CHAPTER 1

INTRODUCTION

Section I. General

l-l. Purpose. This manual presents guidance for the hydraulic design of spillways for flood control or multipurpose dams. Procedures recommended are considered appropriate for structures suitable to most of the field conditions encountered in Corps of Engineer projects. Basic theory is presented as required to clarify presentation and where the state of the art is limited in textbooks. Both laboratory and prototype experimental test results have been correlated with current theory in the design guidance where possible.

l-2. Applicability. This manual applies to all Headquarters, US Army Corps of Engineers (HQUSACE) elements and all field operating activities having responsibilities for the design of Civil Works projects.

l-3. References.

a. National Environmental Policy Act (NEPA), PL 9-190, Section 102(2)(c), 1 Jan 1970, 83 Stat 853.

b. ER 1110-1-8100, Laboratory Investigations and Materials Testing.

c. ER 1110-2-1402, Hydrologic Investigation Requirements for Water Quality Control.

d. ER 1110-2-2901, Construction of Cofferdams.

e. EM 1110-2-1405, Flood Hydrograph Analyses and Computations.

f. EM 1110-2-1601, Hydraulic Design of Flood Control Channels.

g. EM 1110-2-1602, Hydraulic Design of Reservoir Outlet Works.

h. EM 1110-2-1605, Hydraulic Design of Navigation Dams.

i. EM 1110-2-1612, Ice Engineering.

j. EM 1110-2-2400, Structural Design of Spillways and Outlet Works.

k. EM 1110-2-3600, Management of Water Control Systems.

1. Hydraulic Design Criteria (HDC) sheets and charts. Available from Technical Information Division, US Army Engineer Waterways Experiment Station (WES), PO Box 631, Vicksburg, MS 39181-0631.

m. Conversationally Oriented Real-Time Program-Generating system (CORPS) computer programs. Available from: WES Information Technology

Laboratory Computer Program Library (WESLIB), US Army Engineer Waterways Experiment Station, PO Box 631, Vicksburg, MS 39181-0631, and from several US Army Corps of Engineers (CE) computer systems.

Where the above-listed references and this manual do not agree, the provisions of this manual shall govern insofar as spillways and energy dissipators for spillways are concerned.

1-4. Bibliography. Bibliographic items are indicated throughout the manual by numbers (items 1, 2, etc.) that correspond to similarly numbered references in Appendix A. These references are available for loan by request to the Technical Information Division Library, US Army Engineer Waterways Experiment Station, PO Box 631, Vicksburg, MS 39181-0631.

1-5. Symbols. A list of symbols is included as Appendix B, and as far as practical, agrees with the American Standard Letter Symbols for Hydraulics (item 4).

1-6. Other Guidance and Design Aids. Extensive use has been made of the HDC, prepared by WES and USACE. Data and information from Engineer Technical Letters and special reports have also been used. References to the HDC are by HDC chart number. Since HDC charts are continuously being revised, the user should verify that the information used is the most up-to-date guidance. Applicable HDC charts and other illustrations are included in Appendix C to aid the designer. References to specific project designs and model studies have been used to illustrate the structure type; however, the dimensions are not necessarily the recommended dimensions for new projects. WESLIB provides time-sharing computer services to CE Divisions and Districts. One such service is the Conversationally Oriented Real-Time Program-Generating System (CORPS) that-provides the noncomputer-oriented or noncomputer-expert engineer a set of proven engineering applications programs, which can be accessed on several different computer systems with little or no training. See item 45 for instructions on use of the system and a partial list of available programs. Updated lists of programs can be obtained through the CORPS system. References to available programs that are applicable to the design of spillways are noted in this manual by the CORPS program numbers.

1-7. WES Capabilities and Services. WES has capabilities and furnishes services in the fields of hydraulic modeling, analysis, design, and prototype testing. Expertise also exists at WES in the areas of water quality studies, mathematical modeling, and computer programming. Procedures necessary to arrange for WES participation in hydraulic studies of all types are covered in ER 1110-1-8100. WES has the responsibility for coordinating the CE hydraulic prototype test program. Assistance during planning and making the tests is included in this program.

1-8. Design Memorandum Presentation. General and feature design memoranda should contain sufficient information to assure that the reviewer is able to reach an independent conclusion as to the design adequacy. For convenience, the hydraulic information, factors, studies, and logic used to establish such basic spillway features as type, location, alignment, elevation, size, and discharge should be summarized at the beginning of the hydraulic design section. Basic assumptions, equations, coefficients, and alternative designs, etc., should be complete and given in appropriate places in the hydraulic presentation. Operating characteristics and restrictions over the full range of potential discharge should be presented for all release facilities provided.

Section II. Spillway Function, Classification, and Related Studies

l-9. General. Project functions and their overall social, environmental, and economic effects may influence the hydraulic design of the spillway. Optimization of the hydraulic design and operation requires an awareness by the designer of the reliability, accuracy, sensitivity, and possible variances of the data used. The ever-increasing importance of environmental considerations requires that the designer maintain close liaison with other disciplines to assure environmental and other objectives are satisfied in the design. General spillway functions, type of spillways, and related design considerations are briefly discussed in the following paragraphs.

l-10. Spillway Function. The basic purpose of the spillway is to provide a means of controlling the flow and providing conveyance from reservoir to tailwater for all flood discharges up to the spillway design flood (SDF). The spillway can be used to provide flood-control regulation for floods either in combination with flood-control sluices or outlet works, or in some cases, as the only flood-control facility. A powerhouse should not be considered as a reliable discharge facility when considering the safe conveyance of the spillway design flood past the dam. A terminal structure to provide energy dissipation is usually provided at the downstream end of the spillway. The degree of energy dissipation provided is dependent upon the anticipated use of the spillway and the extent of damage that will occur if the terminal structure capacity is exceeded. The standard project flood is a minimum value used for terminal structure design discharge. The designer must keep in mind that damage to the dam structure that compromises the structural integrity of the dam is not acceptable. Acceptance of other damages should be based on an economic evaluation of the extent of damage considering the extremely infrequent flood causing the damage.

l-11. Spillway Classification. Spillways are classified into four separate categories, each of which will serve satisfactorily for specific site conditions when designed for the anticipated function and discharge.

a. Overflow Spillway. This type of spillway is normally used in conjunction with a concrete gravity dam. The overflow spillway is either gated or ungated and is an integral part of the concrete dam structure. See Figure l-l.

b. Chute Spillway. This type of spillway is usually used in conjunction with an earth- or rock-filled dam; however, concrete gravity dams also employ chute spillways. In these cases the dam is usually located in a narrow canyon with insufficient room for an overflow spillway. The chute spillway is generally located through the abutment adjacent to the dam; however, it could

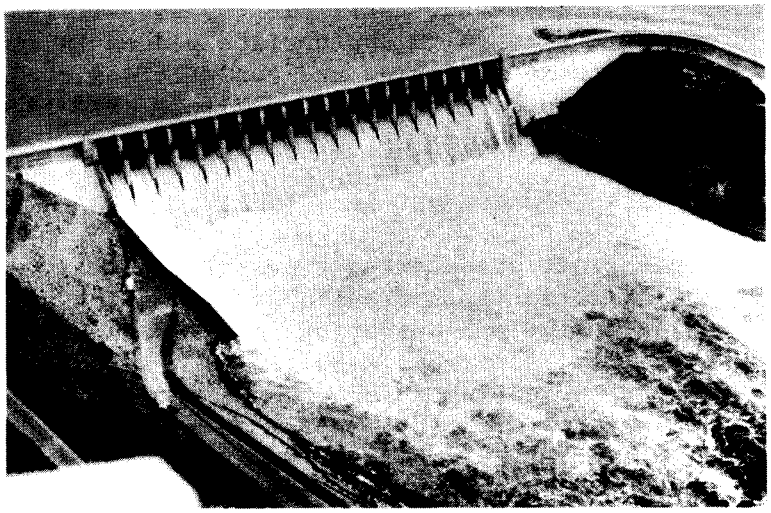
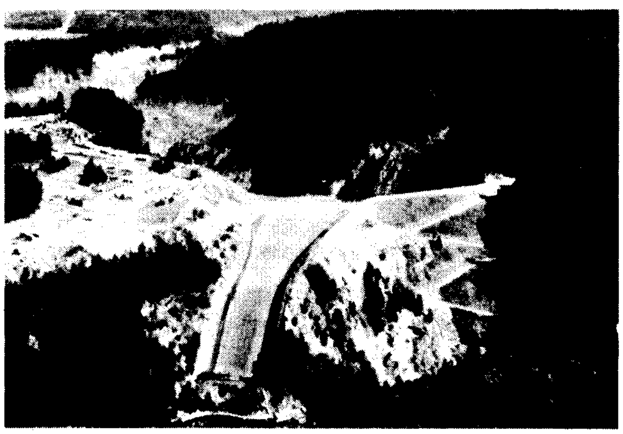
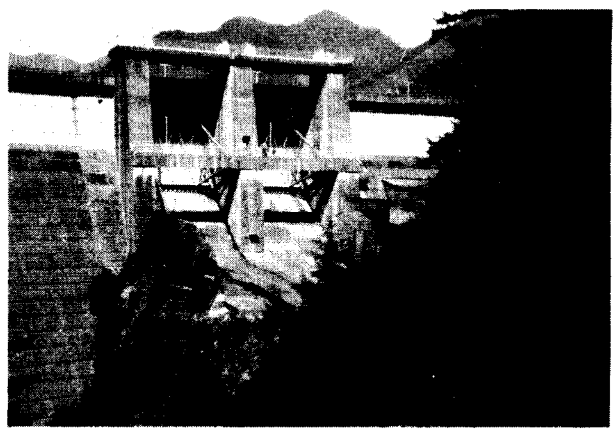


Figure 1-1. Chief Joseph Dam overflow spillway

be located in a saddle away from the dam structure. Examples of chute spillways are shown in Figure 1-2.



Mud Mountain Dam



Wynoochee Dam

Figure 1-2. Chute spillways

c. Side Channel Spillway. This type of spillway is used in circumstances similar to those of the chute spillway. Due to its unique shape, a side channel spillway can be sited on a narrow dam abutment. Side channel spillways generally are ungated; however, there is no reason that gates cannot be employed. Figure 1-3 shows a side channel spillway.

d. Limited Service Spillway. The limited service spillway is designed with the knowledge that spillway operation will be extremely infrequent, and when operation occurs, damage may well result. Damage cannot be to the extent that it would cause a catastrophic release of reservoir water.

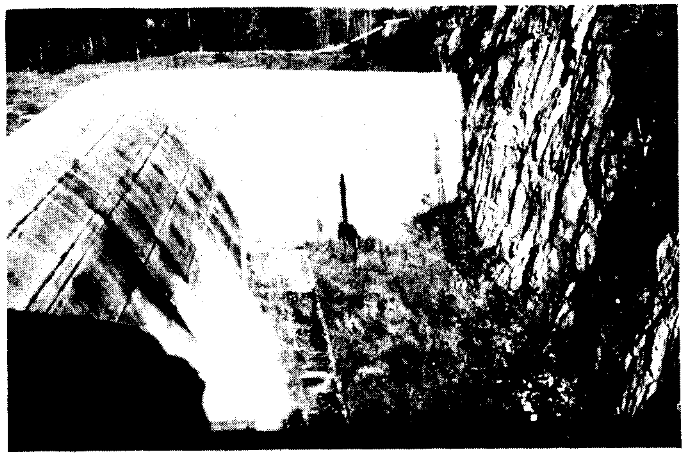


Figure 1-3. Townshend Dam side channel spillway

1-12. Related Studies.

a. Environmental. The general philosophy and guidance for preservation, mitigation, and/or enhancement of the natural environment have been set forth. Many scientific and engineering disciplines are involved in the environmental aspects of hydraulic structures. Some studies influencing the spillway design are briefly discussed below. Pertinent data from these studies should be presented in the design memorandum. The designer is expected to have a working knowledge of these data and their limitations.

(1) Fish and Wildlife. Spillway design and operation may result in damage to downstream fish and wildlife. Flow releases not compatible with naturally seasonable stream quantity and quality can drastically change aquatic life. These changes can result from adverse temperatures and/or nitrogen supersaturation (item 36). The water quality presentation should include information on the expected water quality resulting from spillway use.

(2) Recreation. Recreation needs include fishing, camping, boating, and swimming facilities, scenic outlooks, etc.; and should be considered in the design of spillways, terminal structures, and exit channels. These requirements are usually formulated by the planning discipline in cooperation with local interests. Special consideration should be given to facilities for the handicapped, such as wheelchair ramps to fishing sites below stilling basins. Safety fences are important for the protection of facilities and the public. Appreciable damage to stilling basins has resulted from rocks thrown into the basin by the public. The hydraulic engineer should consider the need for handrails and nonskid walkways, landscaping, and erosion prevention. Rock used for erosion prevention and landscaping should be of a size considerably larger than can be moved by hand.

b. Foundations. The hydraulic design of the spillway and terminal structure can be appreciably affected by the foundation conditions. The spillway and terminal structure type, location, and configuration are usually fixed primarily by foundation and topographic constraints with due consideration within these constraints given to the hydraulic and structural requirements. Foundation information of interest to the hydraulic designer includes composition and depth of overburden, quality of underlying rock, and quality of exposed rock. In addition, side slope stability is of considerable importance in the design of riprap protection. Outflow stage change rates are required for bank stability design. Sufficient foundation data and/or reference to its source should be included or referred to in the hydraulic presentation to substantiate the terminal structure and exit channel design.

c. Environmental Impact Statements. Section 102(2)(c) of the National Environmental Policy Act requires detailed documentation in the project design memoranda on the impact of the planned project on the environment. The hydraulic engineer is expected to have an active part in the preparation of impact statements. An analysis of 234 CE environmental impact statements on various projects is given in item 52. This report can be used as a guide to the type of material needed and format to be used in developing the statements. Basic to the environmental statements are studies to define the preproject and project functions and their effects on the environment. In most cases the effect of each project function must be set forth in detail. A recent publication by Ortolano (item 37) summarizes the concepts involved and presents examples relative to water resources impact assessments. Presentation of the hydraulic design in design memoranda must identify environmental requirements and demonstrate how these are satisfied by the hydraulic facility.

d. Downstream Channel Aggradation and Degradation. Tailwater level changes resulting from either aggradation or degradation can adversely affect the terminal structure performance. The effects of tailwater level changes should be thoroughly investigated to demonstrate that the proposed design will function as intended throughout the project life. The determination of the dominant factors causing riverbed degradation and aggradation is difficult. Changes in the hydrologic characteristics caused by a dam may result in undesirable changes in the elevation of the riverbed. Degradation, or lowering of the riverbed, immediately downstream of a dam may threaten the integrity of the structure. Removal of all or part of the sediment by deposition in the reservoir may induce active bank erosion downstream. Similarly, although the total annual sediment transport capacity of the river will drop significantly, the sediment supplied by downstream tributaries will be unaltered and there may be a tendency for the riverbed to rise. This channel aggradation can increase the flood stages.